Moles, Mass, and Volume Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Table A: Popcorn Kernels Counted in 30 Seconds

Trial #	1	2	3	4	Average
# of kernels counted in 30 s					

Table B: Mass of Popcorn and Marbles

Mass of empty beaker	g
Mass of beaker and 12 popcorn kernels	g
Mass of 12 popcorn kernels	g
Mass of one popcorn kernels	g/kernel
Mass of beaker and 12 marbles	g
Mass of 12 marbles	g
Mass of one marble	g/kernel

Table C: Volumes of Water and Marbles

Mass of 50 mL graduated cylinder	g
Volume of water	mL
Mass of cylinder and water	g
Mass of water	g
Density of water (mass/volume)	g/mL
Initial volume of water in 100 mL graduated cylinder	mL
Volume of water and 12 marbles in cylinder	mL
Volume of 12 marbles	mL
Mass of 12 marbles (From Part B)	g
Density of the marbles (mass/volume)	g/mL

Flame Tests Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Table A: Flame tests results of known and unknown salt solutions

Compound	Color of Flame	Ion Responsible for Flame Color
barium chloride, $BaCl_2$		
barium nitrate, $Ba(NO_3)_2$		
calcium chloride, $CaCl_2$		
calcium nitrate, $Ca(NO_3)_2$		
copper(II) chloride, $CuCl_2$		
copper(II) nitrate, $Cu(NO_3)_2$		
lithium chloride, LiCl		
lithium nitrate, $LiNO_3$		
potassium chloride, KCl		
potassium nitrate, KNO_3		
sodium chloride, NaCl		
sodium nitrate, $NaNO_3$		
strontium chloride, $SrCl_2$		
strontium nitrate, $Sr(NO_3)_2$		
unknown# ______________		
unknown# ______________		

Question 1: Which ion emitted the higher energy photons in the visible region: Cu^{2+} or Sr^{2+}? Explain your answer.

Question 2: Which ion emitted photons with the longer wavelength in the visible region: Li^{+} or Na^{+}? Explain your answer.

Question 3: Which ion emitted the lower frequency photons in the visible region: Ba^{2+} or K^{+}? Explain your answer.

Question 4: The brilliant red color in fireworks is often due to the emission of red light from Sr^{2+}. If the primary wavelength is 650 nm, what is the frequency of this light?

Question 5: From the data collected and the information gained in lecture, would the anion have a dramatic effect on the color of the light emitted? Explain your answer.

Solutions and Spectroscopy Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Part A: Determination of the Concentration of a Copper(II) Ion Solution

Complete the following table.

Data Table A: Calibration Curve of Cu^{2+} Solutions and Unknown

Stock Cu^{2+} solution concentration ______________ M						
Solution #	Target Volume of Cu^{2+}, mL	Actual Volume of Cu^{2+}, mL	Target Volume of H_2O, mL	Actual Volume of H_2O, mL	$[Cu^{2+}]$, M (calculated)	Absorbance at ~620 nm (measured to 3 sf)
1	1.20		4.80			
2	2.40		3.60			
3	3.60		2.40			
4	4.80		1.20			
Equation of Trendline (to three significant figures): $y =$ ________ $x +$ ________				$R^2 =$ ________ (to three significant figures)		
Unknown # ________		Absorbance at 620 (measured) ________		$[Cu^{2+}]$ (calculated) ________ M		

What is the concentration of Cu^{2+} in the solution that you prepared? Show your calculations neatly.

Would you predict the absorbance of Solution 2 to be greater or less than that of Solution 1?

Why?

What is the concentration of Cu^{2+} in your unknown solution? Show your calculation neatly on your worksheet. Record this concentration in Data Table A. (*Hint:* Use the absorbance of the unknown and the trendline to solve for the Cu^{2+} concentration.)

Part B: Preparation of a Copper(II) ion Solution from Solid $CuSO_4 \cdot 5\ H_2O$

You desire to make a copper(II) solution at the same concentration as the unknown you just determined in Part A. How many grams of $CuSO_4 \cdot 5\ H_2O$ are required to make 25.00 mL of this solution?

Show your calculations neatly. Record the result as the target mass in Data Table B.

Data Table B: Preparation of a Cu^{2+} Solution from solid $CuSO_4 \cdot 5\ H_2O$

Target $[Cu^{2+}]$ from Part A, M	Target Mass $CuSO_4 \cdot 5\ H_2O$, g	Actual Mass $CuSO_4 \cdot 5\ H_2O$, g	Absorbance of Cu^{2+} solution at 620 nm	$[Cu^{2+}]$ calculated from absorbance, M

Would you predict the absorbance of your solution made from solid to be greater than or less than that of the unknown solution?

Why?

Part C: Preparation of a Copper(II) Ion Solution by Dilution of a Stock $CuSO_4$ Solution

You desire to make a copper(II) solution at the same concentration as the unknown you determined in Part A. How many mL of the copper(II) stock solution are required to make 25.00 mL of this solution?

Show your calculations neatly on your worksheet. Record the result as the target volume in Data Table C.

Table C: Preparation of a Cu^{2+} Solution from stock Cu^{2+} solution

Stock Cu^{2+} solution concentration ____________________ M				
Target $[Cu^{2+}]$ from Part A, M	Target Volume Cu^{2+} solution, mL	Actual Volume Cu^{2+} solution, mL	Absorbance of Cu^{2+} solution at 620 nm	$[Cu^{2+}]$ calculated from absorbance, M

Would you predict the absorbance of your solution made from a dilution to be greater than or less than that of the unknown solution?

Why?

Solubility Rules Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Table A: Investigating Trends in Solubility

	NH_4^{1+}	K^{1+}	Ca^{2+}	Sr^{2+}	Mg^{2+}	Al^{3+}	Fe^{3+}	Zn^{2+}
Cl^{1-}								
ClO_4^{1-}								
OH^{1-}								
CO_3^{2-}								
SO_4^{2-}								
PO_4^{3-}								

Additional Observations:

Question 1: In general, are compounds containing ammonium ions or ions from Group 1 on the Periodic Table soluble or insoluble?

Question 2: What exceptions did you find to the Group 1 rule?

Question 3: Are compounds containing an ion with either a +1 or a -1 charge soluble or insoluble?

Question 4: What exceptions did you find to the charge rule?

Question 5: In general, are compounds containing the carbonate anion soluble or insoluble?

Question 6: What exceptions did you find to the carbonate ion rule?

Question 7: In general, are compounds containing the sulfate anion soluble or insoluble?

Question 8: What exceptions did you find to the sulfate ion rule?

Question 9: In general, are compounds containing the phosphate anion soluble or insoluble?

Question 10: What exceptions did you find to the phosphate ion rule?

Question 11: Considering the general rules you found for Group 1 ions and phosphate ion, which rule takes precedence?

Question 12: State a general rule that relates the solubility of an ionic compound with the charges on the ions of which it is composed.

Question 13: In your Data Table A, write the chemical formula for any compound that precipitated. Pay attention to charges on the ions; the number of positive charges in the formula should equal the number of negative charges.

Question 14: Write balanced net ionic equations for reactions that produced a precipitate containing magnesium ion, (Mg^{2+}).

Table B: Investigating Some Exceptions to the Solubility Rules

	Ag^{1+}	Pb^{2+}
Cl^{1-}		

Additional Observations:

Question 15: What exceptions did you observe by mixing Ag^{1+} with Cl^{-} and Pb^{2+} with Cl^{-}?

Question 16: In your Data Table B, write the chemical formula for any compound that precipitated. Pay attention to charges on the ions; the number of positive charges in the formula should equal the number of negative charges.

Question 17: Write balanced net ionic equations for reactions that produced a precipitate in Data Table B.

Qualitative Analysis Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Table A: Confirmatory Tests for Individual Ions*

Ion	Part	Solution	Results of adding KI solution*
Ag^{1+}	A	Well plate solution	
Ag^{1+}	B	solution from HCl	
Ag^{1+}	B	solution from hot water	
Ag^{1+}	B	solution from ammonia	
Hg_2^{2+}	A	Well plate solution	
Hg_2^{2+}	B	Solution from HCl	
Hg_2^{2+}	B	Solution from hot water	
Hg_2^{2+}	B	Solution from ammonia	
Pb^{2+}	A	Well plate solution	
Pb^{2+}	B	Solution from HCl	
Pb^{2+}	B	Solution from hot water	
Pb^{2+}	B	Solution from ammonia	

*If there was a precipitate, rather than a clear solution, fill in this space with NA.

Table B: Solubility of Individual Ions

	Ag^{1+}	Hg_2^{2+}	Pb^{2+}
Soluble in HCl			
Soluble in hot water			
Soluble in ammonia			

Question 1: Which ions, if any, can you separate by their solubility in HCl?

Question 2: Which ions, if any, can you separate by their solubility in hot water?

Question 3: Which ions, if any, can you separate by their solubility in NH_3?

Question 4: How do your results from the confirmatory tests in Part A compare with the confirmatory tests performed on the solutions from individual ions in Part B? Can the observations be used to determine which ions are present in solution?

Question 5: Complete the flow chart below for the known solutions. It will serve as a reference as you test your separation scheme. At each branch in the flow chart, you should list the ions that exist as solid compounds on the left, under the label "insoluble." List ions that exist in solution on the right, under the label "soluble." There should be from zero to three entries on each line. At the end, the ions should be separated and each of the three ions should be present at different places on the flow chart.

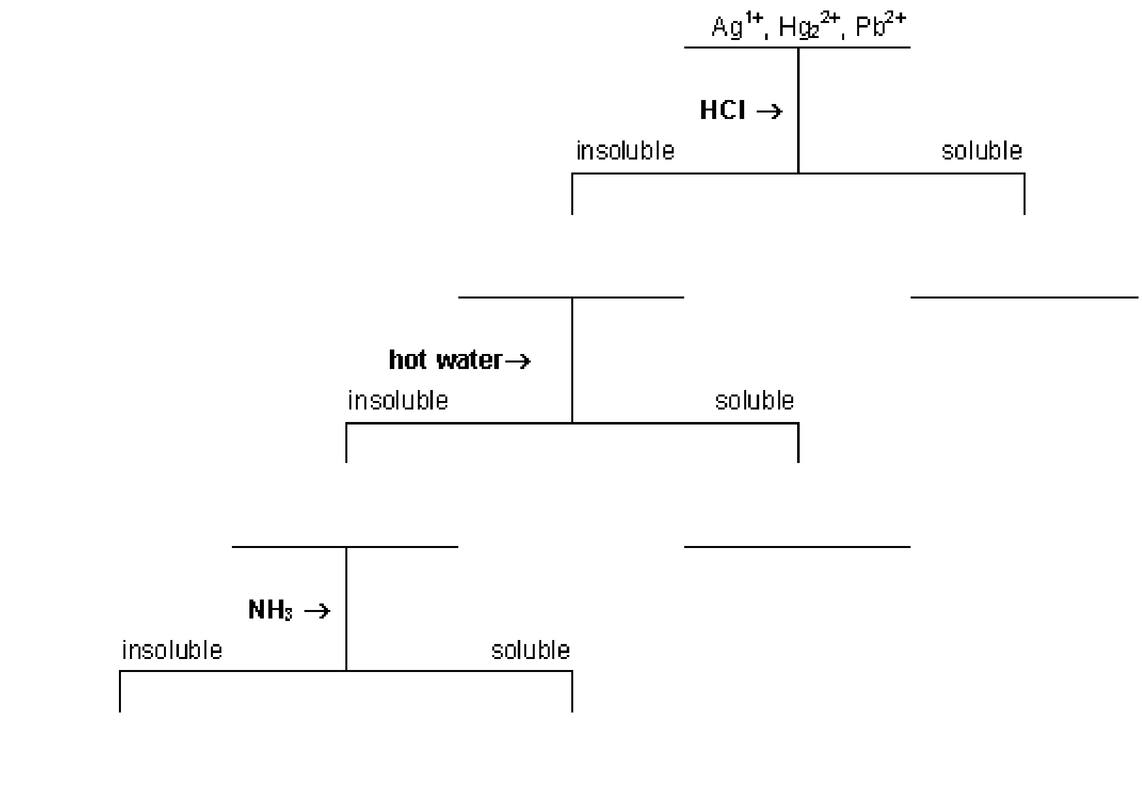

Figure 1: Flow Chart for Separation of Mixture of Ag^{+}, $Hg_2{}^{2+}$, Pb^{2+}. Each "soluble" branch should be tested with KI to confirm the presence of an ion.

Table C1: Solubility of a Mixture of Ag^{+}, $Hg_2{}^{2+}$, Pb^{2+}

	Mixture of Ag^{1+}, Hg_2^{2+}, Pb^{2+}
Soluble in HCl	
Soluble in hot water	
Soluble in ammonia	

Table C2: Confirmatory Tests for Ions in Mixture of Ag^{+}, Hg_2^{2+}, Pb^{2+}

Solution	Results of adding KI solution
Supernatant from HCl addition	
Supernatant from hot water	
Supernatant from ammonia	

Question 6: Based on your confirmatory tests, describe where the soluble ions ended up. Were they where your flow chart predicted?

Table D1: Solubility of Unknown Mixture # ____________

	Unknown Mixture
Soluble in HCl	
Soluble in hot water	
Soluble in ammonia	

Table D2: Confirmatory Tests for Ions in Unknown Mixture

Solution	Results of adding KI solution
Supernatant from HCl addition	
Supernatant from hot water	
Supernatant from ammonia	

Question 7: Unknown # ____________ contained the following ions: ____________.

Molecular Geometry Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Table A: Exploring Simple Structures

Molecules	Bond Lengths (Å)	Bond Orders	Bond Angles (°)	Hybridization on Central Atom	Molecular Shape
N_2O	NN: NO:	NN: NO:			
SO_2	SO: SO:	SO: SO:			
CH_2O	CO: CH: CH:	CO: CH: CH:			
H_2O	OH: OH:	OH: OH:			
NH_3	NH: NH: NH:	NH: NH: NH:			
CH_4	CH: CH: CH: CH:	CH: CH: CH: CH:			

Question A1: For each of the six molecules, how did your Lewis structures compare to the molecular models and the models on the computer? Were they the same or different? Explain.

Question A2: For each of the six molecules, was your Lewis structure a good and accurate representation of the molecule's actual shape? Explain why or why not.

Question A3: Did the model set and computer models help you identify the molecular shape better than the Lewis structures? Do you think models are helpful with 3D visualization?

Question A4: Did you have any other interesting observations? Please elaborate.

Table B: Bond Order vs Bond Length

Molecules	Bond Lengths ($\mathring{A}$)	Bond Orders	Hybridization on Carbons
C_2H_6	CC:	CC:	
C_2H_4	CC:	CC:	
C_2H_2	CC:	CC:	

Question B1: What conclusions can you draw about bond order and bond length?

Question B2: Looking back at your data in Part A, are all single bonds the same length? Based on these observations, can you make a generalization about the length of all single bonds compared to double bonds or all double bonds compared to triple bonds? What general rule can you make?

Question B3: Did you have any other interesting observations? Please elaborate.

Table C: Resonance Structures

Molecules	Bond Lengths Lengths (Å)	Bond Orders	Bond Angles (°)	Hybridization
C_6H_6	CC: CC: CC: CC: CC: CC:	CC: CC: CC: CC: CC: CC:	CCC:	C's:
CO_3^{2-}	CO: CO: CO:	CO: CO: CO:	OCO:	C:
SCN^{1-}	CS: CN:	CS: CN:	SCN:	C:

Question C1: Which of the three molecules had resonance structures that were equal? Which did not? Explain.

Question C2: How can you confirm that the resonance structures are equal for a molecule? Explain.

Question C3: If there was a molecule with unequal resonance structures, which structure is the best according to the computer modeling? Can you tell which structure the computer is displaying? How? Do your observations agree with what you have learned about formal charge?

Question C4: Did you have any other interesting observations? Please elaborate.

Solid State Modeling Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Question A1: Looking from above, how much of the atom is inside the shaded region?

Question A2: The corner of a cubic unit cell such as this one is *defined by the center (nucleus) of the atom at the corner.* How much of this atom is above the nucleus **and** inside the shaded region (inside the unit cell)?

Question A3: How many total atoms are inside the unit cell (defined by the centers of the eight spheres)?

Question A4: Using a ruler, measure the length of a side of your unit cell in cm. (Remember, the unit cell is defined by the nuclei of the atoms!) What is the volume of your unit cell?

Question A5: We will define "atom density" for our unit cells as the number of spheres that can pack into a cubic centimeter. What is the "atom density" (spheres/cm^3) for your simple cubic cell?

Question A6: Noting as before that the corner of the unit cell is defined by the nucleus of this atom, how much of this atom is inside the unit cell?

Question A7: Focus on the layer 2 atom. How much of this atom is inside the unit cell?

Question A8: How many total atoms are inside the unit cell?

Question A9: Using a ruler, measure the length of a side for this unit cell. What is the volume (in cm^3) of this unit cell?

Question A10: What is the "atom density" (spheres/cm^3) for your body centered cubic cell?

Question A11:

a. Comparing this structure (body centered cubic) to the last structure (simple cubic), which one *appears* to have less void volume?

b. Compare your observation to your calculated "atom densities" for these two structures. Do your calculations confirm your observation?

Question A12: Focus on a layer 2 atom. How much of this atom is inside the unit cell?

Question A13: How many total atoms are inside the unit cell?

Question A14: Using a ruler, measure the length of a side of this unit cell. What is the volume (in cm^3) of this unit cell?

Question A15: What is the "atom density" (in spheres/cm^3) for your face centered cell?

Question A16:

a. Comparing this structure (face centered cubic) to the last structure (body centered cubic), which one *appears* to have less void volume?

b. Compare your observation to your calculated "atom densities" for these two structures. Do your calculations confirm your observation?

Question A17: Comparing the "atom densities" of all three cubic unit cells, rank them in packing efficiency, with the most efficiently packed cell listed first.

Question B1: Focus on *only* the colorless spheres. What type of cubic structure do they appear to be arranged in?

Question B2: Focus on *only* the blue spheres. What type of cubic structure do they appear to be arranged in? (You may need to build another set of layers 2 and 2 to see this.)

Question B3:

a. How many colorless spheres are inside the unit cell?

b. How many blue spheres are inside the unit cell?

c. What is the ratio of colorless to blue spheres in the unit cell?

d. What is the chemical formula for sodium chloride?

e. Do your results in part c reflect the correct stoichiometry in sodium chloride?

f. Based on your knowledge of trends in ionic radii, which spheres represent sodium ions and which represent chloride ions?

Question B4:

a. Focus on the central, colorless sphere of layer 1'. How many blue spheres are in contact with it? (You may need to build another set of layers 2 and 2 to see this.) This is its coordination number.

b. Focus on the central, blue sphere of layer 2. How many colorless spheres are in contact with it?

Question B5: Focus on *only* the colorless spheres. What type of cubic structure do they appear to be arranged in?

Question B6:

a. How many colorless spheres are inside the unit cell?

b. How many green spheres are inside the unit cell?

c. What is the ratio of colorless to green spheres in the unit cell?

d. What is the chemical formula for cesium chloride?

e. Do your results in part c reflect the correct stoichiometry in cesium chloride?

f. Based on your knowledge of trends in ionic radii, which spheres represent cesium ions and which represent chloride ions?

Question B7: Focus only on the cube made by the 8 green spheres.

a. What type of cubic structure do the green spheres appear to be arranged in?

b. What is the ratio of colorless to green spheres?

Question B8: Using a ruler, compare the length of the side of a cube with colorless spheres on the corners to one with green spheres.

a. Do they have the same volume?

b. Are these both acceptable unit cells for cesium chloride? Why or why not?

Question B9:

a. Focus on one of the green spheres in layer 2. How many colorless spheres are in contact with it?

b. Focus on the colorless sphere at the center of the green cornered cube. How many green spheres are in contact with it?

Question B10:

a. Focus on *only* the colorless spheres. What type of cubic structure do they appear to be arranged in?

b. Focus on *only* the green spheres. What type of cubic structure do they appear to be arranged in?

Question B11: Putting the two ions together in this arrangement gives the "fluorite" structure. The name is derived from the mineral fluorite, which contains calcium fluoride.

a. How many colorless spheres are inside the unit cell?

b. How many green spheres are inside the unit cell?

c. What is the ratio of colorless to green spheres in a unit cell?

d. What is the chemical formula of calcium fluoride?

e. Do your results in part c reflect the correct stoichiometry in calcium fluoride?

f. Which spheres represent calcium ions and which represent fluoride ions?

Freezing Point Depression Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Complete the following tables and answer the questions below. (All masses must be reported to three decimal places and all temperatures must be reported to one decimal place.)

Data Table A: Measuring the Freezing Point of Stearic Acid

Mass of 30 mL beaker	g
Mass of 30 mL beaker plus stearic acid	g
Mass of stearic acid	g
Measured freezing point of stearic acid (first trial)	°C
Measured freezing point of stearic acid (second trial)	°C
Average measured freezing point to stearic acid	°C

Data Table B: Freezing Point Depression by a Solute, Lauric Acid

	First Solution	Second Solution
Mass of 30 mL beaker (from Part A)	—	—
Mass of 30 mL beaker and contents	g	g
Mass of 30 mL beaker plus stearic and lauric acids	g	g
Total mass of lauric acid	g	g
Colligative molality (m_c) of the solution (Your stearic acid mass from Table A is not accurate. Please use your original beaker tare and the necessary data from Table B.)	m	m
Predicted ΔT_{f} (Assume that k_{f} is known to two significant figures, 4.5°C/m.)	°C	°C
Theoretical freezing point of the solution (To calculate, use the last entry for your average freezing point from Data Table A to the 0.1°C.)	°C	°C
Measured freezing point of the solution	°C	°C

In Part B, for the first solution made by adding lauric acid, did you expect the freezing point to be at a higher or lower temperature than that of the pure solvent stearic acid?

Using your measured amounts of stearic acid and lauric acid for the first addition, calculate the colligative molality (m_c) of the resulting solution, the freezing point depression (ΔT_f) this molality should cause and the theoretical freezing point of the solution. Enter your results in Data Table B.

In Part B, for the first solution made by adding lauric acid, how did your measured freezing point compare to your theoretical freezing point?

In Part B, for the first solution made by adding lauric acid, calculate the % difference. The equation for percent difference is:

% difference = ((theoretical value − actual value) × 100%)/theoretical value.

A percent difference can be positive or negative.

% difference =

In Part B, for the second solution made by adding lauric acid, did you expect the freezing point to be at a higher or lower temperature than that of the pure solvent stearic acid?

Using your measured amounts of stearic acid and lauric acid for the second addition, calculate the colligative molality (m_c) of the resulting solution, the freezing point depression (ΔT_f) this molality should cause, and the theoretical freezing point of the solution. Enter your results in Data Table B.

In Part B, for the second solution made by adding lauric acid, how did your measured freezing point compare to your theoretical freezing point?

In Part B, for the second solution made by adding lauric acid, calculate the % difference. The equation for percent difference is:

% difference = ((theoretical value − actual value) × 100%)/theoretical value.

A percent difference can be positive or negative.

% difference =

Equilibrium and Le Chatelier's Principle PreLab Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Table A: Observations for the Equilibrium: $Fe^{3+} + SCN^{-} \rightleftharpoons FeSCN^{2+}$

Well #	Stress Applied	Observations Upon Applying Stress
1	None; control for comparison	
2	Add 0.10 M $Fe(NO_3)_3$	
3	Add 0.05 M NaSCN	
4	Add 1.0 M $AgNO_3$	
5	Add 1.0 M $NaNO_3$	

Question 1: When $Fe(NO_3)_3$ was added to the system,

a. Which ion in the equilibrium system caused the "stress"?

b. Which way did the equilibrium shift?

c. What happened to the concentration of SCN^{-}?

d. What happened to the concentration of $FeSCN^{2+}$?

Question 2: When NaSCN was added to the system,

a. Which ion in the equilibrium system caused the "stress"?

b. Which way did the equilibrium shift?

c. What happened to the concentration of Fe^{3+}?

d. What happened to the concentration of $FeSCN^{2+}$?

Question 3: When $AgNO_3$ was added to the system, it caused the precipitation of solid AgSCN.

a. Which ion in the equilibrium had its concentration changed by addition of $AgNO_3$?

b. Did the concentration of that ion increase or decrease?

c. When $AgNO_3$ was added, which way did the equilibrium shift?

Question 4: When you added $NaNO_3$, did anything happen? Can you explain this result?

Table B: Observations for the Equilibrium: $CoCl_4^{2-} + 6\ H_2O \rightleftharpoons Co(H_2O)_6^{2+} + 4\ Cl^-$

Exp't	Stress Applied	Observations Upon Applying Stress
Well 1A	Add 12 M HCl	
Well 1B	Add water	
Well 2A	Add 12 M HCl	
Well 2B	Add 1.0 M $AgNO_3$	
Beaker 1	Heat Solution	
Beaker 2	Cool Solution	

Question 5: Adding HCl has the effect of adding Cl^- ions to the system. When Cl^- was added to the system,

a. Which way did the equilibrium shift?

b. What happened to the concentration of $CoCl_4^{2-}$?

c. What happened to the concentration of $Co(H_2O)_6^{2+}$?

Question 6: When water was added to the system,

a. Which way did the equilibrium shift?

b. What happened to the concentration of $CoCl_4^{2-}$?

c. What happened to the concentration of $Co(H_2O)_6^{2+}$?

Question 7: When you added $AgNO_3$, it caused the precipitation of solid AgCl.

a. Which ion in the equilibrium had its concentration changed by addition of $AgNO_3$?

b. Did the concentration of that ion increase or decrease?

c. When $AgNO_3$ was added, which way did the equilibrium shift?

Question 8: State a general rule concerning a system at equilibrium when more of one of the components is added.

Question 9: State a general rule concerning a system at equilibrium when one of the components is removed.

Question 10: For the $CoCl_4^{2-} + 6\ H_2O \rightleftharpoons Co(H_2O)_6^{2+} + 4\ Cl^-$ Equilibrium

a. Which way did the equilibrium shift upon heating?

b. Which way did the equilibrium shift upon cooling?

c. A general rule concerning temperature changes to equilibrium systems is that the input of energy (raising the temperature) shifts the equilibrium to the higher energy side of the equilibrium. Based on your observations, which side of the equilibrium is the higher energy side?

d. Is the reaction, $CoCl_4^{2-} + 6\ H_2O \rightleftharpoons Co(H_2O)_6^{2+} + 4\ Cl^-$ endothermic or exothermic?

Titrations Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Table A1: Titration of Vinegar

	Trial 1	Trial 2	Trial 3
Mass of Flask	g	g	g
Volume of Vinegar	mL	mL	mL
Mass of Flask + Vinegar	g	g	g
Mass of Vinegar	g	g	g
Concentration of NaOH	M	NA	NA
Initial Buret Reading	mL	mL	mL
Final Buret Reading	mL	mL	mL
Volume of Titrant Added	mL	mL	mL

Question 1: Calculate the number of millimoles of NaOH required to reach the endpoint for each trial. Show one calculation completely. What is the average? Record the values in Data Table A2.

Question 2: How many millimoles of acetic acid are in each vinegar sample? Show one calculation completely. What is the average? Record the values in Data Table A2.

Question 3: What is the mass of acetic acid in each vinegar sample? Show one calculation completely. What is the average? Record the values in Data Table A2.

Question 4: What is the molarity of acetic acid in each vinegar sample? Show one calculation completely. What is the average? Record the values in Data Table A2.

Question 5: What is the mass % of acetic acid in each vinegar sample? Show one calculation completely. What is the average? Record the values in Data Table A2.

Table A2: Calculation Results for Titration of Vinegar

	Trial 1	Trial 2	Trial 3	Average
mmol of NaOH				
mmol of $HC_2H_3O_2$				
Mass of $HC_2H_3O_2$	g	g	g	g
Molarity of $HC_2H_3O_2$ in Vinegar	M	M	M	M
Mass % of $HC_2H_3O_2$ in Vinegar				

Acid-Base Studies Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Table A: pH Measurements of Some Common Acid and Base Solutions.

Solution #	Solution	pH
1	0.10 M HCl	
2	0.010 M HCl	
3	0.0010 M HCl	
4	0.10 M $HC_2H_3O_2$	
5	0.10 M NaOH	
6	0.010 M NaOH	
7	0.10 M NH_3	

Question 1: Based on your observations in Data Table A, classify each of the following as a strong acid, strong base, weak acid or weak base.

a. HCl

b. $HC_2H_3O_2$

c. NaOH

d. NH_3

Question 2:

a. What happened to the pH when the 0.10 M HCl was diluted to 0.010 M?

b. What happened to the pH when the 0.10 M NaOH was diluted to 0.010 M?

c. State a general rule about what happens to the pH of acidic or basic solutions when they are diluted with pure water.

Table B: Acidity and Basicity of Some Household Chemicals

Substance	pH	Acid, Base, or Neutral
Vinegar		
Bleach		
Vitamin C		
Lemon Juice		
Baking Soda		
Dishwasher Detergent		
Carbonated Water		
Baking Powder		
Ammmonia		

Question 3:

a. List all of the household chemicals that you found to be acidic.

b. List all of the household chemicals that you found to be basic.

c. List all of the household chemicals that you found to be neutral.

Table C: HCl + NaOH

mL NaOH	pH
0.0	
3.0	
6.0	
12.0	

Question 4: Based on your observations in Data Table C, classify each of the resulting solutions as acidic, basic or neutral.

a. HCl + 0.0 mL NaOH

b. HCl + 3.0 mL NaOH

c. HCl + 6.0 mL NaOH

d. HCl + 12.0 mL NaOH

Measuring Enthalpy Changes Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Table A: Heat of Solution

Initial temperature of water	°C
Temperature of solution after addition to $CaCl_2$	°C
ΔT_{1A} (T_{final} - $T_{initial}$) for dissolution of $CaCl_2$	°C
Initial temperature of water	°C
Temperature of solution after addition to NH_4NO_3	°C
ΔT_{2A} (T_{final} - $T_{initial}$) for dissolution of NH_4NO_3	°C

Question 1: For dissolution of $CaCl_2$, please answer a - c.

a. Was heat given off or absorbed? Could you feel it?

b. Was the process exothermic or endothermic?

c. Did the entropy increase, decrease, remain the same or can you not tell from your results?

Question 2: For dissolution of NH_4NO_3, please answer a - c.

a. Was heat given off or absorbed? Could you feel it?

b. Was the process exothermic or endothermic?

c. Did the entropy increase, decrease, remain the same or can you not tell from your results?

Question 3: Which chemical would you use in a cold pack, $CaCl_2$ or NH_4NO_3?

Table B: Heat of Reaction

	Temperature	Observations
Initial $FeCl_3$ solution	°C	
Solution after addition of NaOH	°C	
ΔT_{1B}	°C	

Question 4: For the reaction of $FeCl_3$ and NaOH, please answer a - d.

a. What evidence indicates that a reaction occurred?

b. Did the reaction give off or absorb heat? Could you feel it?

c. Did the entropy increase, decrease, remain the same or can you not tell from your results?

d. Was the reaction spontaneous? Justify your answer.

Table C: Heat of Neutralization

	Temperature	Observations
Initial NaOH solution	°C	
Solution after addition of water	°C	
ΔT_{1C}	°C	
Solution after addition of HCl	°C	
ΔT_{2C}	°C	
Solution after addition of HNO_3	°C	
ΔT_{3C}	°C	
Solution after addition of$HC_2H_3O_2$	°C	
ΔT_{4C}	°C	

Question 5: In which test tubes was there evidence for a reaction?

Question 6:

a. Were the temperature changes about the same or very different for the reactions?

b. Can you account for this result? Hint: write the reaction equations and compare them.

Question 7: Did the entropy increase, decrease, remain the same or can you not tell from your results?

Table D: Temperature and Time During the Heating of Water

Elapsed time, min	Temperature, °C	Observations
0.0		
0.5		
1.0		
1.5		
2.0		
2.5		
3.0		
3.5		
4.0		
4.5		
5.0		
5.5		
6.0		
6.5		
7.0		
7.5		
8.0		
8.5		
9.0		
9.5		
10.0		

Elapsed time, min	Temperature, °C	Observations
13.0		
13.5		
14.0		
14.5		
15.0		
15.5		
16.0		
16.5		
17.0		
17.5		
18.0		
18.5		
19.0		
19.5		
20.0		
20.5		
21.0		
21.5		
22.0		
22.5		
23.0		

Elapsed time, min	Temperature, °C	Observations
10.5		
11.0		
11.5		
12.0		
12.5		

Elapsed time, min	Temperature, °C	Observations
23.5		
24.0		
24.5		
25.0		

Record the following.

Time at which all the ice has (just) melted	min
Time at which bubbles first appear	min
Time at which steam first appear	min
Time at which true boiling begins	min

Question 8:

a. Were there times when the temperature stayed constant for several readings?

b. What was happening during these times?

Question 9: What happened to the entropy of the system for each of the following processes? Did it increase greatly, increase slightly, decrease greatly, decrease slightly, stay the same or can you not tell from your results?

a. As the ice melted?

b. As the water was heated?

c. As the water boiled?

Redox Reactions Worksheet

As you work through the steps in the lab procedures, record your experimental values and the results on this worksheet.

Table A: Reactions of Oxidizing Agents

	Cu^{2+}	Mg^2+	MnO_4^{1-}
H_2O_2			
KI			

Question 1: List the oxidizing agents in order, from weakest to strongest.

Question 2: Write half-reactions for the oxidizing agents in order, from weakest to strongest. *(Hint: Remember that oxidizing agents get reduced.)*

Table A2: Reactions of Reducing Agents

	Cu	Mg	Zn
H_2O_2			
KI			

Question 3: List the reducing agents in order, from strongest to weakest.

Question 4: Write the half-reactions for the reducing agents in order, from weakest to strongest. *(Hint: Remember that reducing agents get oxidized.)*

Question 5: The strongest oxidizing agent is said to have the most positive potential and the strongest reducing agent has the most negative potential. Based on your observations, list all the half-reactions (as reductions) in order from most negative to most positive.

Question 6: Consider the reaction involving magnesium metal.

a. With what compound, element or ion did magnesium react?

b. Write a half-reaction for what happened to this chemical. You may use a Table of standard Reduction Potentials[1] for help.

c. Write the balanced equation for the reaction that occurred between magnesium metal and this chemical.

Question 7: You also observed a reaction with zinc metal.

a. With what compound, element or ion did zinc react?

[1] ../tables/tables.pdf

b. Write a half-reaction for what happened to this chemical. You may use a Table of standard Reduction Potentials[2] for help.

c. Write the balanced equation for the reaction that occurred between zinc metal and this chemical.

Question 8: Based on your answers to Question 5, will either of these combinations produce a reaction?

a. $Cu + Mg^{2+}$

b. $Cu^{2+} + Mg$

Table B1: Cell Potentials vs a Cu^{2+}/Cu Couple

Electrochemical Cell	Half-Cell Being Studied	Measured Potential Difference vs Cu^{2+}/Cu in mV	Measured Potential Differences vs Cu^{2+}/Cu in V
Copper-Copper	Cu^{2+}/Cu		
Silver-Copper	Ag^{1+}/Ag		
Lead - Copper	Pb^{2+}/Pb		
Zinc-Copper	Zn^{2+}/Zn		

[2] ../tables/tables.pdf

Table B2: Cell Potentials in Order, with Half-Reactions

Half-Cell	Measured Cell Potential (Most negative to most positive)	Calculated Cell Potential vs SHE (Add +0.34 V)	Standard Reduction Potential vs SHE from table
/	V	V	V
/	V	V	V
/	V	V	V
/	V	V	V

Question 9: Based on the order obtained by experiment,

a. Which species has the highest energy filled or partially filled orbitals?

b. Which species has the lowest energy unfilled or partially filled orbitals?

c. Which species is the strongest reducing agent?

d. Which species is the strongest oxidizing agent?

Question 10: Using the order you found in Data Table B2 for the cell potentials, write the half-reaction for each half-cell. Write the reactions as reductions.

Question 11: The Mg^{2+}/Mg couple was not tested when measuring half-cell potentials. Based on its behavior in Part A, where would you place it in Data Table B2? (If you are doing Part B first, return to this question after completing both parts of the lab.